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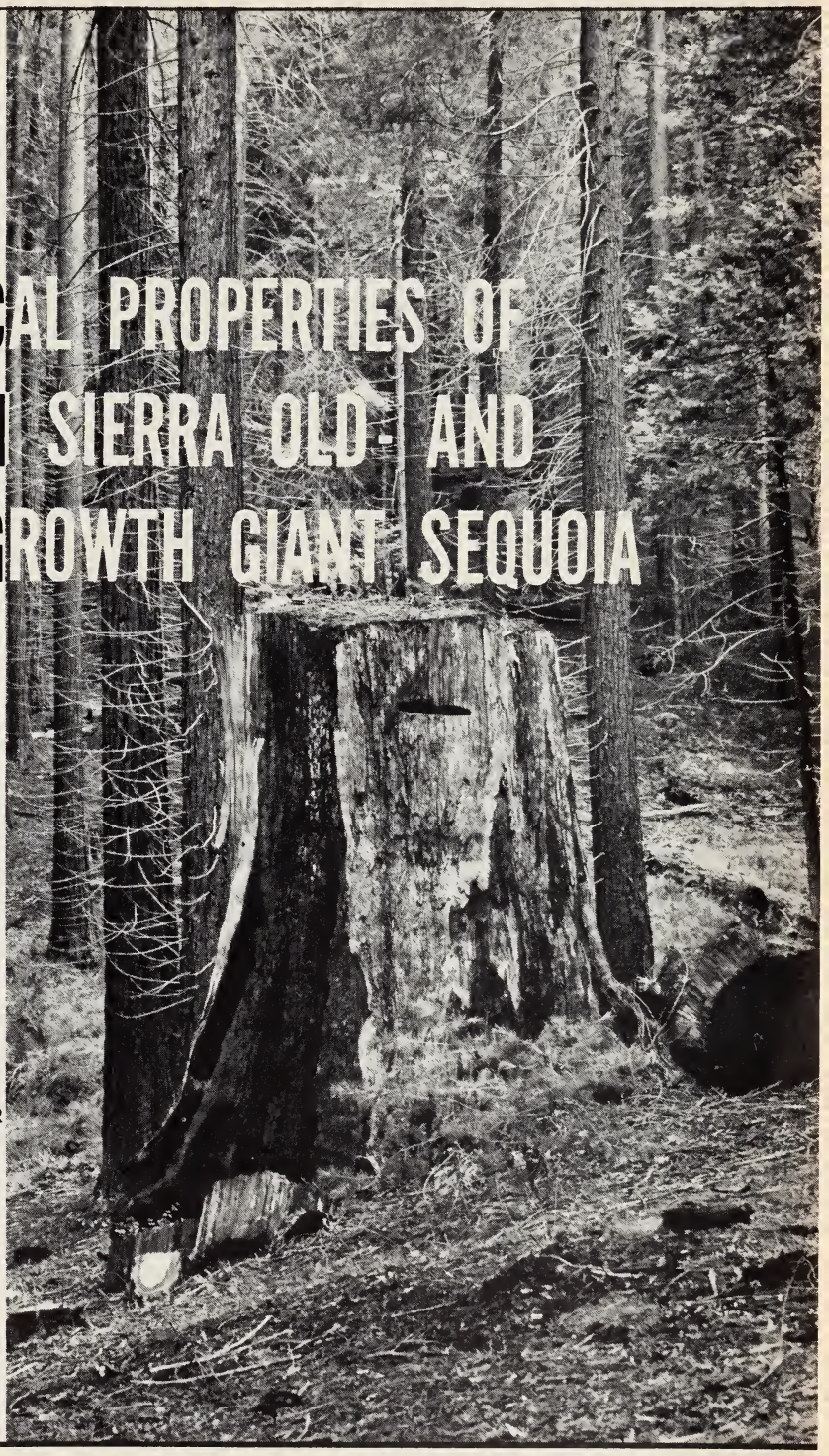

MECHANICAL PROPERTIES OF SOUTHERN SIERRA OLD- AND SECOND-GROWTH GIANT SEQUOIA

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This bulletin reports the results of strength tests, density, shrinkage, and fiber measurements on wood of young- and old-growth giant sequoia trees from the southern Sierra. It compares these values with those of coast redwood and Sierra white fir and concludes that the wood of the young-growth trees is satisfactory for use as construction material and pulpwood.

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MECHANICAL PROPERTIES OF SOUTHERN SIERRA OLD- AND SECOND-GROWTH GIANT SEQUOIA[1]

INTRODUCTION

Giant sequoia [*Sequoia gigantea* (Lindl.) Decne.], which is famous for its size and longevity, is restricted to more or less isolated small groves of large old trees in the central and southern Sierra Nevada mountains of California. Although *S. gigantea* has been essentially overlooked as having potential value as a timber-producing species, its relatively limited second-growth stands have good rate of growth (Wensel and Schoneheide, 1971), good tree form and freedom from insect and disease attack (Fowells, 1965). Accordingly, it seemed worthwhile to assemble data on mechanical and certain related physical properties of the wood, such as density, shrinkage and fiber length, in order to assess suitability of the species for commercial forest planting.

Old-growth giant sequoia has long been regarded as lighter and more brittle than the coast redwood but, as reported by Sudworth (1908), "it is said not to be less valuable for lumber." It was among the indigenous woods tested by S. P. Sharples and reported by C. S. Sargent (1884). He described bending specimen failures as "square break on tension side" and his data showed seasoned wood of giant sequoia to be definitely weaker than coast redwood and white fir in bending and stiffness but equivalent to them in maximum crushing strength along the grain. (These were exploratory tests quite different from present ASTM procedures, 1952.)

Although no data on mechanical properties of native-grown second-growth giant sequoia were available, R. Keylwerth (1954) reported on tests of wood from five planted trees grown and tested in Germany using DIN procedures. These trees averaged 26.6 meters high and test material came from sections 28 to 38 cm in diameter with 38 to 44 rings. Keylwerth stated that, in comparison with coast redwood, Douglas fir, and spruce, this wood was inferior only with respect to tensile strength, and that wood of both sequoias is inferior to Douglas fir and spruce in resistance to impact loading. His tests showed little difference in strength between heartwood and sapwood, and a high variability which he attributed to grain deviation resulting from presence of many small sound knots. He indicated that the wood was suitable for construction, furniture, boxes, small casks, boat building and core veneer, and that the high natural durability of the heartwood recommended it for hot-bed frames.

E. J. Martin (1958) reports "That the grain and the color of *Sequoiadendron giganteum* (giant Sequoia) wood are also of interest to the wood-working industry may be seen from the fact that, in Rheydt, a veneer plant offered DM 600 (about $150) for the trunk of a 75-year-old tree. Since the wood can be excellently polished, it is useful for many purposes in interior architecture, for inlays, and for furniture."

MATERIALS AND METHODS

Second-growth wood for testing was obtained from several trees in young-growth stands which had grown up after logging in the 1870's (Biswell, *et al.*, 1966) in Whitaker's Forest (a 320-acre University of California research tract adjacent to the western edge of Sequoia National Park with elevation range of 5200 to 6200 feet). These trees had been either knocked to the ground by old-growth

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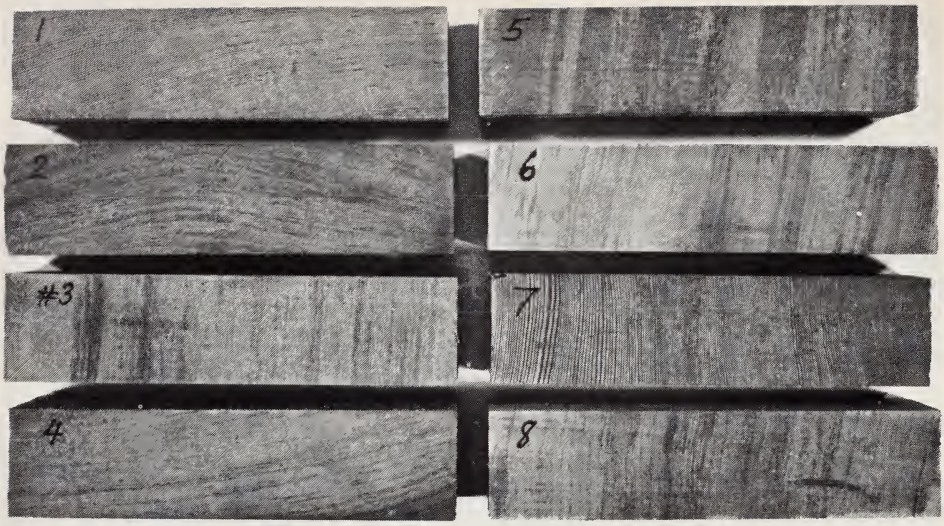


Fig. 1. Cross sections of old-growth giant sequoia planks

trees that fell, or had been damaged or blown down by winter storms. Table 1 (tables start page 9) gives information on trees and location of test logs.

Opportunity to obtain some of the old-growth material used for testing came unexpectedly when it was learned that the Sequoia Forest Products Company of Dinuba was about to saw some logs from fallen trees in the Mountain Home State Forest located east of Porterville. Planks 3 inches × 12 inches × 8 feet in length were obtained from eight different quarter-log sections in the course of 1½ days' sawing at the mill. Location of test planks in the trees could not be determined, nor could it be ascertained how many different trees were represented. The logs from which the planks came were between 8 to 12 feet in diameter and had well over 1,000 rings. Figure 1 shows cross sections of the planks; table 2 shows the number of growth rings in each plank.

Bolts approximately 4 feet long were cut from logs of the younger trees and sawn into 2½ × 2½ inch test blanks following generally the procedure presented in ASTM designation D 143-52 (ASTM). Exploratory tests of specific gravity, shrinkage and bending were made on green material from tree E. Test blanks from 4-foot bolts of all other trees were divided arbitrarily into two groups, one to be tested green and the other at the air-dry condition (approximately 12 per cent moisture content). The presence of many small knots and the small diameter of some logs limited the amount of clear 2 × 2 inch test blanks. Where only limited clear material was available, a larger number of blanks was tested green.

Each plank from old-growth logs was divided into four test-blank strips somewhat larger than 2½ × 2½ inches in cross section. Two of these provided specimens for green tests and the other two for dry tests. At least one specimen was selected from each strip for each of the tests.

All mechanical tests and the specific gravity and volumetric shrinkage determinations conformed to ASTM D 143–52. Tangential, radial and longitudinal shrinkage was determined by measuring dimensional changes to the nearest 0.001-inch on 1 × 1 × 4-inch specimens cut with the growth rings aligned so as to permit exact measurements in the tangential and radial directions. Tangential and radial measurements were taken in the middle of the 4-inch blocks, and longitudinal measurements were taken in the 4-inch direction.

Fiber-length data were obtained by macerating matchstick-size samples of wood with an aqueous solution of 10 per cent nitric and 10 per cent chromic acids, staining with Bismark brown and mount-

ing directly on slides in dilute polyvinyl acetate. Averages were based on 40 measurements of fibers selected at random from slides of each sample (Echols, 1969).

RESULTS AND DISCUSSION

Table 3 (page 10) lists basic data for the various mechanical and physical properties of green second-growth wood; table 4 lists the same for dry second-growth wood. Since the number of tests for each property varied for different trees, mean values were determined from trees means rather than individual test values to give each tree equal weight (Cockrell, 1959). Table 5 gives data for both green and dry wood of old-growth.

Moisture content. Moisture content of second-growth green wood averaged well over 100 per cent. Some sapwood exceeded 200 per cent, while some heartwood was as low as 60 per cent. Dry wood was tested at approximately 12 per cent moisture content, with actual values ranging from 11 to 16 per cent. Adjustment to 12 per cent was made with the U. S. Forest Products Laboratory exponential formula, using the intersection point (Mp) 25 as suggested in the Wood Handbook (1955). The old-growth material, all heartwood, had moisture content ranging between 85 and 165 per cent, with most specimens from 5 of the 8 planks being over 120 per cent. Dry tests were made at

Fig. 2. Cross section of second-growth tree number 2 at height of 16 feet

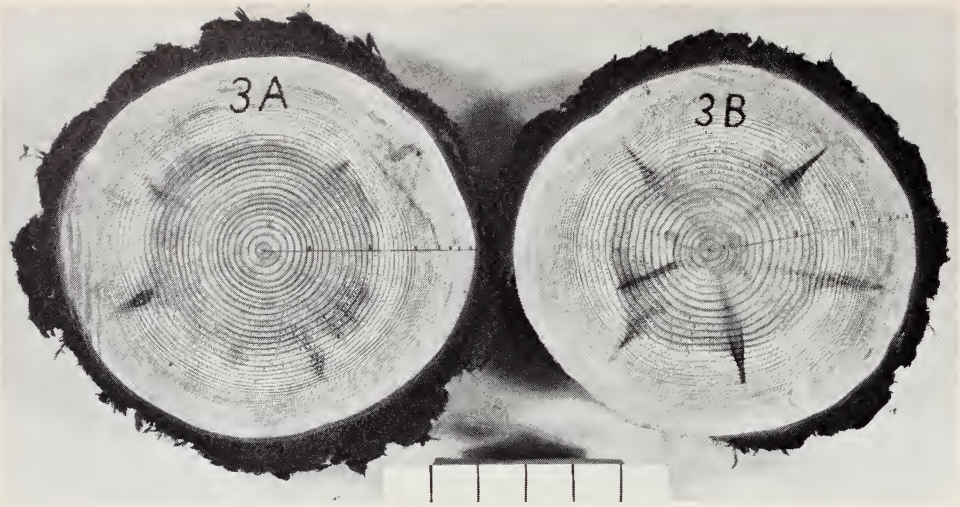


Fig. 3. Cross sections of second-growth tree number 3 at heights of 8.5 and 14 feet

a moisture content between 11 and 11.5 per cent.

Growth rate. The growth pattern of young trees had the ring width decreasing from the pith outward as is typical for dominant forest-grown conifers. Growth rate in the central core (within 25 rings from pith) was consistently about 7 to 10 rings per inch. Out toward the bark the number of rings per inch increased from 10 to 20, or even higher in the case of tree number 3 whose outer 50 rings ranged from 18 to 40 rings per inch. All trees had zones of sapwood 2 to 4 inches thick containing 25 to 45 growth rings (about 60 rings in tree number 3). Figures 2 and 3 show the ring pattern and sapwood zones for trees 2 and 3. Individual old-growth test specimens ranged from 17 to 44 rings per inch with the exception of a few from plank number 7, one of which had only 11 rings per inch (see figure 1 and table 2).

Structural qualities. Table 6 compares second-growth and old-growth giant sequoia with second-growth and old-growth coast redwood [*Sequoia sempervirens* (D. Don) Endl.] and white fir [*Abies concolor* (Gord. and Glend.) Lindl.] on the basis of selected mechanical properties. It is evident that second-growth giant sequoia is slightly heavier and stronger than second-growth coast redwood, and decidedly heavier and stronger than most of the wood of old-growth giant sequoia tested in this study. (Specific gravity of heartwood specimens tested by Sharples [Sargent, 1884] averaged 0.32 [based on oven-dry volume and weight], the same as that in table 5.) Second-growth test specimens were preponderantly sapwood, and the static bending specimens failed consistently in splintering tension. This contrasted sharply with the brash type of failures characteristic of most of the old-growth specimens in this study. The one dense specimen of old-growth, plank number 7 with a specific gravity of 0.37, had a splintering tension flexural failure and its strength values approached second-growth values; it had green values of 3800 psi maximum crushing strength, 6450 psi modulus of rupture, and 830,000 psi modulus of elasticity. By contrast, plank number 3, with the lowest specific gravity (0.27) had values of 1800, 4000, and 325,000 respectively. Second-growth sapwood test blanks used in this study machined satisfactorily, and superficially resembled white fir. They had essentially the same average specific gravity, shrinkage, and green moisture content as the German-grown material tested by Keylwerth (1954) and previously mentioned. Since this study shows second-growth giant sequoia to be equal to or somewhat superior to white fir and second-growth redwood in most of its mechanical properties, it can be recommended as acceptable for dimension grades of lumber to be

used for light construction.

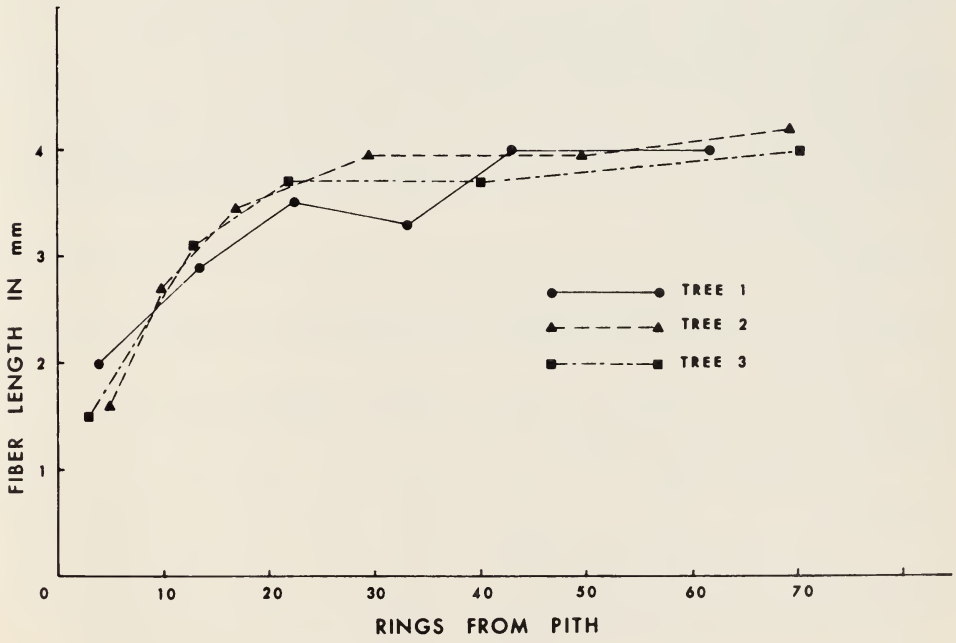
Shrinkage. Table 7 present data on longitudinal, tangential, radial, and volumetric shrinkage and compares them to some shrinkage data for heartwood of coast redwood. Heartwood specimens showed appreciably lower tangential, radial, and volumetric shrinkage than did sapwood, with the old-growth figures being decidedly lower than the second-growth. The great majority of the second-growth specimens elongated slightly when air-dried (12 to 15 per cent moisture content) but showed some shrinkage (most of them under 0.10 per cent) at the oven-dry condition. There was considerable variation in shrinkage among the eight old-growth quarter logs sampled, as there also was in mechanical properties. Dense material from plank number 7 showed higher radial, tangential, and volumetric shrinkage, and lower longitudinal shrinkage than did the others. Shrinkage of second-growth heartwood of giant sequoia in general resembled that of coast redwood.

Fiber length. Figure 4 (below) shows the relationship of fiber length to rings from pith in cross sections about 18 feet above the ground for three young-growth trees. The fibers averaged about 3.5 mm in length at 20 rings from the pith, and approached 4 mm at 50 rings. Maximum values for individual fibers 20 rings and farther out ranged from 4.3 to 5.6 mm, with most of them being close to 5 mm.

Average fiber length for the eight old-growth specimens was 4.5 mm, with individual averages ranging from 4.1 to 4.8. Maximum individual fiber lengths ranged from 5.7 to 7.0 mm, with six specimens having a maximum above 6.0; specimen number 7 had the lowest maximum (5.7 mm). Separate averages were calculated for springwood and summerwood fiber length for this specimen and were almost identical, being respectively 4.37 mm and 4.41 mm.

A comparison with fiber-length characteristics of coast redwood presented by Resch and Arganbright (1968) reveals that both young-growth and old-growth giant sequoia have significantly shorter fibers, and that the rate of increase of length with rings from pith resembles more the typical conifer pattern that "tapers off after the first 10 to 30 years of tree life," rather than remaining high like coast redwood during the first 50 years of growth.

Fig. 4. Relationship of fiber length to rings from pith of three second-growth giant sequoias



SUMMARY

Strength and certain other related physical properties data are reported for second-growth and old-growth giant sequoia wood grown under natural forest conditions in the southern Sierra. Second-growth wood, much of it sapwood, was distinctly superior to old-growth (all heartwood), which proved to be much lighter and more brittle. Wood from the young trees was equal in most strength properties to second-growth redwood and old-growth white fir and is recommended for use in light construction. Shrinkage properties of heartwood of both second-growth and old-growth giant Sequoia are quite similar to comparable categories of coast redwood; sapwood has much higher shrinkage values than heartwood. Fibers of giant sequoia wood are shorter than coast redwood; their length averages 4 to 4.5 mm which is slightly higher than the average length for conifers generally.

ACKNOWLEDGMENTS

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TABLE 1

AGE AND SIZE OF TREES AND LOCATION OF TEST BOLTS IN TREES

Tree number	Rings at stump	D.B.H.†	Total height	Bolt	Bolt location and size			
					Large end		Small end	
					Height	D.I.B.‖	Height	D.I.B.
		inches	*feet*		*feet*	*inches*	*feet*	*inches*
E	84	11.7	67‡		3.0	10.7	8.0	8.9
1	80+	19.9	85§	A	16.0	14.4	20.0	14.0
				B	20.0	14.0	24.0	13.8
2	84	19.4	113	A	3.0	18.4	7.5	15.2
				B	16.0	13.8	20.5	13.7
				C	28.0	13.2	32.5	12.9
				D	51.5	11.2	56.0	10.8
3	83	10.5	94	A	8.5	8.5	13.6	8.2
				B	13.8	8.2	18.2	7.8
4	86	15.1	81¶	A	8.0	12.0	12.5	11.6
5	86*	15.7	96	A	10.0	13.4	14.5	12.6
				B	14.5	12.6	19.0	12.0
6	86*	20.6	109	A	31.0	13.9	35.5	13.3

*Estimated since from same stand as Tree No. 4.
†Diameter outside bark 4.5 ft. above ground.
‡Broken top.
§9″ D.O.B. at 85′ where top broken off and not possible to reconstruct.
¶Spike top rubbing against pine tree for 33 yrs.
‖Diameter inside bark.

TABLE 2

NUMBER OF GROWTH RINGS IN OLD-GROWTH TEST PLANKS

Plank number	Number of rings	Radius	Rings per inch
		inches	
1	76	3.1	24.5
2	88	3.1	28.4
3	395	12.6	31.4
4	99	3.0	33.0
5	379	12.3	30.8
6	281	12.5	22.5
7	217	12.3	17.6
8	288	12.5	23.0

TABLE 3

MECHANICAL PROPERTIES OF GREEN SECOND-GROWTH GIANT SEQUOIA

Property	Tree number, number of specimens tested, and magnitude of property							Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
	Tree number										
	E	1	2	3	4	5	6				
Specific gravity:	(4)†	(14)	(25)	(4)	(18)	(9)	(8)				
Volume green, weight oven-dry	0.38	0.36	0.37	0.36	0.33	0.36	0.32	0.35	0.02	0.29	0.44
Volume oven-dry, weight oven-dry		0.40	0.44	0.41	0.36	0.39	0.34	0.39	0.04	0.33	0.48
Static bending:		(6)	(23)	(6)	(4)‡	(8)	(4)				
Fiber stress at proportional limit (psi)*	3,680.0	4,110.0	4,080.0	4,290.0	4,300.0	4,030.0	3,860.0	4,050.0	220.0	3,020.0	4,940.0
Modulus of rupture (psi)	6,710.0	6,860.0	6,910.0	6,480.0	6,520.0	6,840.0	6,390.0	6,670.0	210.0	5,930.0	8,080.0
Modulus of elasticity (1,000 psi)	1,050.0	1,250.0	1,330.0	1,190.0	1,100.0	960.0	1,090.0	1,140.0	130.0	720.0	1,540.0
Work to proportional limit (in.-lb. per cu. in.)	0.71	0.77	0.70	0.89	0.95	0.98	0.77	0.82	0.11	0.43	1.51
Work to maximum load (in.-lb. per cu. in.)	7.3	5.7	6.6	6.3	5.6	9.0	6.6	6.7	1.2	2.8	13.2
Total work (in.-lb. per cu. in.)	17.6	16.7	14.0	19.5	12.8	18.8	9.1	15.5	3.7	6.4	30.9
Compression parallel to grain:		(12)	(27)	(2)	(3)	(9)	(4)				
Stress at proportional limit (psi)		2,550.0	3,330.0	2,560.0	2,520.0	2,580.0	2,330.0	2,640.0	350.0	1,380.0	4,250.0
Maximum crushing strength (psi)		3,760.0	4,080.0	3,010.0	3,560.0	3,270.0	3,400.0	3,510.0	380.0	2,183.0	4,450.0
Compression perpendicular to grain:		(8)	(27)	(5)	(5)	(11)	(6)				
Stress at proportional limit (psi)		300.0	340.0	350.0	370.0	520.0	380.0	380.0	80.0	250.0	663.0
Toughness:		(15)	(75)	(28)	(11)	(9)	(12)				
(in.-lb.)		183.0	248.0	241.0	180.0	258.0	170.0	210.0	40.0	102.0	497.0
Hardness:		(6)	(37)	(5)	(6)	(11)	(5)				
Side (lb.)		360.0	420.0	410.0	430.0	440.0	390.0	410.0	30.0	304.0	521.0
End (lb.)		490.0	570.0	510.0	480.0	530.0	440.0	500.0	40.0	413.0	657.0
Maximum shearing strength parallel to grain:		(17)	(50)	(6)	(6)	(16)	(7)				
(psi)		720.0	820.0	750.0	680.0	790.0	720.0	740.0	60.0	550.0	1,026.0
Cleavage:		(15)	(44)	(5)	(5)	(12)	(6)				
(lb. per in. of width)		160.0	160.0	150.0	150.0	170.0	140.0	160.0	10.0	68.0	220.0
Maximum tensile strength perpendicular to grain:		(15)	(44)	(5)	(3)	(11)	(7)				
(psi)		260.0	250.0	230.0	260.0	320.0	260.0	260.0	30.0	160.0	428.0
Maximum tensile strength parallel to grain:		(8)	(21)	(8)	(4)	(8)	(6)				
(psi)		9,600.0	10,500.0	11,790.0	10,670.0	8,860.0	10,370.0	10,300.0	1,000.0	6,535.0	16,200.0

*Pounds per square inch.
†Numbers in parentheses refer to number of specimens tested for each property.
‡These bending specimens were 1 × 1 × 16 inches. (ASTM D 143-52 Secondary Method).

TABLE 4

MECHANICAL PROPERTIES OF AIR-DRY SECOND-GROWTH GIANT SEQUOIA

Property	Tree number, number of specimens tested, and magnitude of property						Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
	Tree number									
	1	2	3	4	5	6				
Specific gravity:	(25)†	(4)	(4)	(18)	(4)	(8)				
Volume oven-dry, weight oven-dry	0.40	0.44	0.41	0.36	0.39	0.34	0.39	0.04	0.33	0.48
Static bending:	(6)	(6)	(2)	(6)‡	(4)	(3)				
Fiber stress at proportional limit (psi)*	6,350.0	5,970.0	7,090.0	7,210.0	4,360.0	4,910.0	5,980.0	1,150.0	3,820.0	8,020.0
Modulus of rupture (psi)	10,230.0	10,040.0	10,640.0	9,470.0	7,820.0	7,860.0	9,340.0	1,220.0	6,920.0	11,270.0
Modulus of elasticity (1,000 psi)	1,425.0	1,590.0	1,320.0	1,160.0	1,020.0	1,250.0	1,290.0	200.0	750.0	1,760.0
Work to proportional limit (in.-lb. per cu. in.)	2.14	1.26	2.11	2.53	1.04	1.06	1.69	0.64	0.93	4.0
Work to maximum load (in.-lb. per cu. in.)	7.3	7.4	13.4	6.10	7.8	7.5	8.3	2.6	4.3	16.1
Total work (in.-lb. per cu. in.)	14.8	23.1	21.4	10.7	16.8	11.5	16.4	5.1	5.1	29.7
Compression parallel to grain:	(9)	(6)			(4)	(2)				
Stress at proportional limit (psi)	3,750.0	5,125.0	.....	.....	3,110.0	3,800.0	3,950.0	850.0	1,970.0	6,140.0
Maximum crushing strength (psi)	5,770.0	6,438.0	.....	.....	4,710.0	4,700.0	5,405.0	850.0	4,510.0	7,190.0
Compression perpendicular to grain:	(8)	(10)	(2)		(7)	(3)				
Stress at proportional limit (psi)	620.0	640.0	625.0	.....	525.0	440.0	570.0	85.0	360.0	790.0
Toughness:	(35)	(7)	(1)	(9)	(6)	(8)				
(in.-lb.)	161.0	221.0	241.0	127.0	162.0	186.0	183.0	42.0	69.0	297.0
Hardness:	(7)	(10)	(2)		(5)	(4)				
Side (lb.)	480.0	520.0	510.0	.....	480.0	370.0	470.0	60.0	340.0	600.0
End (lb.)	780.0	850.0	770.0	.....	690.0	610.0	740.0	90.0	590.0	1,020.0
Maximum shearing strength parallel to grain:	(11)	(13)	(3)		(5)	(3)				
(psi)	890.0	990.0	1,110.0	.....	940.0	780.0	940.0	120.0	730.0	1,140.0
Cleavage:	(15)	(9)	(2)		(7)	(2)				
(lb. per in. of width)	120.0	130.0	140.0	.....	140.0	130.0	130.0	8.0	100.0	180.0
Maximum tensile strength perpendicular to grain:	(12)	(11)	(4)		(4)	(2)				
(psi)	220.0	200.0	190.0	.....	330.0	210.0	230.0	60.0	100.0	410.0
Maximum tensile strength parallel to grain:	(4)			(5)	(5)	(4)				
(psi)	9,490.0	.....	.....	8,690.0	11,840.0	11,560.0	10,400.0	1,550.0	7,770.0	15,120.0

*Pounds per square inch.
†Numbers in parentheses refer to number of specimens tested for each property.
‡These bending specimens were 1 × 1 × 16 inches. (ASTM D 143-52 Secondary Method).

TABLE 5

MECHANICAL PROPERTIES OF OLD-GROWTH GIANT SEQUOIA*

Property	Green				Air-dry			
	Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value	Species mean	Standard deviation of tree means	Minimum individual test value	Maximum individual test value
Specific gravity:								
Volume green, weight oven-dry	0.30	0.03	0.26	0.40				
Volume oven-dry, weight oven-dry	0.32	0.03	0.28	0.43				
Static bending:								
Fiber stress at proportional limit (psi)	3,200.0	641.0	2,000.0	4,330.0	4,010.0	928.0	2,490.0	6,040.0
Modulus of rupture (psi)	5,200.0	744.0	3,620.0	6,615.0	5.870.0	919.0	4,410.0	7,880.0
Modulus of elasticity (1,000 psi)	560.0	147.0	283.0	858.0	680.0	116.0	519.0	858.0
Work to proportional limit (in.-lb. per cu. in.)	1.03	0.21	0.66	1.3	1.27	0.6	0.64	2.5
Work to maximum load (in.-lb. per cu. in.)	5.3	1.5	2.9	7.7	3.2	0.8	2.2	4.9
Total work (in.-lb. per cu. in.)	6.1	2.2	2.9	11.9	3.4	0.8	2.2	4.9
Compression parallel to grain:								
Stress at proportional limit (psi)	2,140.0	607.0	1,060.0	3,560.0	2,900.0	446.0	2,330.0	3,700.0
Maximum crushing strength (psi)	2,730.0	583.0	1,650.0	4,040.0	4,420.0	455.0	3,830.0	5,280.0
Compression perpendicular to grain:								
Stress at proportional limit (psi)	230.0	82.0	95.0	440.0	745.0	126.0	560.0	932.0
Toughness:								
(in.-lb.)	73.0	35.0	43.0	210.0	47.0	16.0	27.0	76.0
Hardness:								
Side (lb.)	280.0	73.0	190.0	480.0	360.0	33.0	315.0	395.0
End (lb.)	430.0	78.0	300.0	590.0	740.0	75.0	630.0	880.0
Maximum shearing strength parallel to grain:								
(psi)	730.0	82.0	570.0	880.0	970.0	106.0	800.0	1,140.0
Cleavage:								
(lb. per in. of width)	150.0	19.0	110.0	190.0	120.0	27.0	100.0	160.0
Maximum tensile strength perpendicular to grain:								
(psi)	250.0	33.0	180.0	330.0	205.0	36.0	130.0	280.0
Maximum tensile strength parallel to grain:								
(psi)	6,170.0	1,310.0	3,600.0	8,080.0	5,380.0	1,400.0	3,370.0	8,570.0

*Mean value based on tests of 2 specimens each from 8 quarter logs.

TABLE 6

COMPARISON OF GIANT SEQUOIA WITH COAST REDWOOD AND WHITE FIR

Description of tree	Specific gravity‡	Modulus of rupture	Modulus of elasticity	Total work	Maximum crushing strength	Compression perpendicular to grain	Hardness		Shear	Cleavage
							End	Side		
		psi	*1000 psi*	*in.-lb. per cu. in.*	*psi*	*psi*	*lb.*	*lb.*	*psi*	*lb. per in. of width*
Green:										
Giant sequoia second-growth	0.35	6670	1140	15.5	3510	380	500	410	740	150
Giant sequoia old-growth	0.30	5200	558	6.1	2725	230	430	280	730	150
Coast redwood second-growth*	0.34	5900	960	9.3	3110	270	520	350	890	160
Coast redwood old-growth†	0.38	7500	1180	15.2	4200	520	570	410	800	170
White fir†	0.35	5700	1030	11.4	2710	370	380	330	750	170
Dry:										
Giant sequoia second-growth	0.38	9340	1290	16.4	5400	570	740	470	940	130
Giant sequoia old-growth	0.31	5870	680	3.4	4420	740	740	360	970	120
Coast redwood second-growth*	0.35	7900	1100	5.2	5220	520	740	420	1110	140
Coast redwood old-growth†	0.40	10,000	1340	8.8	6150	860	790	480	940	150
White fir†	0.37	9300	1380	11.4	5350	600	730	440	930	160

*U.S.F.S. Research Paper FPL 53 (1966).
†U.S.D.A. Tech. Bul. No. 479 (1935).
‡Based on volume at test and weight oven-dried.

TABLE 7

SHRINKAGE PER CENT OF SECOND-GROWTH AND OLD-GROWTH GIANT SEQUOIA

Item	Number of second-growth trees or old-growth bolts	Green to air-dry				Green to oven-dry				
		Longitudinal§	Tangential	Radial	T/R¶	Longitudinal§	Tangential	Radial	T/R¶	Vol.
		Sapwood								
Average	7	−0.04	3.8	2.0	2.0	0.06	7.5	3.8	2.0	11.1
Standard deviation		0.04	0.7	0.6	0.3	0.04	0.8	0.7	0.2	1.3
		Heartwood								
Second-growth										
Average	5	−0.05	2.3	1.0	2.3	0.04	4.9	2.2	2.2	7.5
Standard deviation		0.06	0.4	0.2	0.3	0.06	0.9	0.2	0.2	1.5
Old-growth*										
Average	8	0.09	1.6	0.8	2.1	0.24	3.0	1.3	2.4	5.0
Standard deviation		0.10	0.3	0.3	0.4	0.17	0.7	0.4	0.4	0.85
Plank number 7	1	−0.05	2.4	1.6	1.5	0.00	4.4	2.6	1.7	7.0
		Heartwood of coast redwood								
Second-growth										
Average†	24	−0.03	2.3	0.7	3.3	0.12	5.2	2.2	2.4	
Average‡	24	0.04	2.2	0.8	2.8	0.19	4.9	2.2	2.2	
Old-growth										
Average†	24	−0.02	1.4	0.7	2.0	0.11	4.0	2.1	1.9	

*Two specimens from each plank, including number 7.
†Schniewind (1963).
‡U.S. Forest Service Res. Paper FPL 53 (1966)
§Negative values represent elongation.
¶T/R is ratio of tangential to radial shrinkage.

To simplify the information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

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